PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to Centrifuging Apparatus

We, NATIONAL RESEARCH DEVELOPMENT CORPORATION, 1, Tilney Street, London, W.1., a British Corporation established by Statute, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to centrifuging apparatus and in particular, though not exclusively, to centrifuging apparatus suitable for oxygenating blood, for example during the performance of surgical operations.

Blood oxygenators are known in which the blood to be oxygenated is fed on to rotary horizontal or vertical discs and oxygen is blown over the surface of the blood on the discs. Other oxygenators consist of vertical plates down which the blood is allowed to trickle and oxygen is caused to flow upwards in countercurrent.

These known devices suffer from various disadvantages, such as slow speed of operation, the need to prime the device with a large quantity of blood before blood can be fed back into the patient, and the need to provide separate filtration, cooling (or warming) and pumping devices.

One object of this invention is to provide centrifuging apparatus of improved construction and/or performance.

Another object of the present invention is to provide apparatus which can be used as a blood oxygenator and in which the above disadvantages are substantially lessened or overcome.

According to the present invention centrifuging apparatus comprises a rotatable container having within it at least one centrifuge member defining a tortuous path of large surface area extending between an axially located inlet opening and at least one peripherally disposed outlet opening, means for delivering fluid to be centrifuged to said inlet opening and means for collecting said fluid from said outlet opening, whereby when said centrifuge member is rotated fluid introduced through said inlet opening is spread upon said surface and progressed filmwise toward said outlet opening by centrifugal action.

The apparatus also preferably includes a further opening, which may serve to admit oxygen and/or other gases to said inlet opening.

The said tortuous path is conveniently provided by a succession of frusto-conical sleeve-like surfaces of successively increasing diameters. The outer-most portion is conveniently further encircled by an outer wall of the container, to serve as a jacket for circulating cooling or warming fluids, e.g. water.

Preferably when the apparatus is designed for use as a blood oxygenator the container is of relatively short dimensions and the tortuous path preferably runs from one end of the container to the other and then reverses to the first mentioned end and so on, so that the tortuous path can be of considerable length. By this means a compact container can be designed and the apparatus may be primed with a relatively small initial volume of blood. The blood used for priming the apparatus may be obtained initially from the patient undergoing an operation or it may be obtained from a separate supply, in which case after the initial priming of the apparatus the patient's own blood may be fed into the apparatus.

Furthermore, in the case of a centrifuging apparatus designed for use as a blood oxygenator, the apparatus in use is preferably rotated at a sufficiently high speed to ensure that the blood will flow through the apparatus in the form of a very thin film. By this

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means a thin film of blood on a large surface area is obtained so that the chemical combination of oxygen with the blood is facilitated. Furthermore, the fact that the blood is forced through a rapidly rotating container will ensure that the formation of air bubbles in the blood is automatically avoided and that any existing bubbles are dispersed.

Also in the case of a centrifuging apparatus designed for use as a blood oxygenator, the apparatus preferably includes a scoop, which in operation is maintained stationary and projects into the path of the blood emanating from the said outlet opening. Alternatively, instead of employing a scoop, the apparatus may include a peripheral flange, co-operating with a discharge outlet having an outlet pipe or like connection, by means of which blood may be fed back to the patient.

The invention is of particular value in the case of centrifuging apparatus designed for use as a blood oxygenator, since it enables the apparatus to be made of small size, for example of a volume of 250 ccs. and also enables blood to be passed rapidly through the apparatus, for example at a rate of the order of 1200 ccs. per minute. An oxygenator in accordance with the invention can in many cases be so constructed as to require no separate filter, pump(s), or heat-exchanger(s). Another application of the invention would appear to be to the oxygenation of the culture media for the cultivation of bacteria or other organisms requiring large supplies of oxygen and/or other gases.

Further applications of the invention will readily occur to those familiar with centrifuging apparatus in general. For example apparatus in accordance with the invention may be designed for filtering or reclaiming lubricating oil. A further and more general application of the invention is to the filtering of fluids in general, in which case if the above-mentioned tortuous path is provided by a succession of frusto-conical sleeve-like portions of successively increasing diameters, these portions may be made of a porous filtering medium.

Two embodiments of the invention will now be described with reference to Figures 1 to 4 of the drawings accompanying the Provisional Specification and Figures 5 and 6 of the accompanying drawings, in which:—

Figure 1 is a sectional elevation of one form of centrifuging apparatus, the section being taken along the longitudinal axis of the apparatus,

Figure 2 is a front elevation of that part of the apparatus of Figure 1 extending to the right of the line 2—2 of Figure 1,

Figure 3 is a view similar to Figure 1, but in which part only is shown, of an alternative form of centrifuging apparatus, and

Figure 4 is a front elevation of the apparatus of Figure 3 extending to the right of the line 4—4 of Figure 3.

Figure 5 is a longitudinal sectional elevation of an alternative form of apparatus according to the invention and

Figure 6 is a cross-sectional view of the apparatus depicted in Figure 5.

The apparatus of Figure 1 comprises a cylindrical container A, which has a plurality of internal annular passageways B. At least one axial inlet opening C_1 (or alternatively C_2) is provided as shown. The apparatus also includes a peripherally disposed annular outlet opening D, shown more clearly in Figure 2, is the form of four substantially quadrantal slots. An axial sleeve E (alternatively tube C_2) serves for guiding a fluid or other medium to be centrifuged into the inlet opening.

When the fluid or other medium is fed into the apparatus it will first impinge on the annular surface B_1, and when the container is rotated at high speed, the fluid etc. will be forced rapidly towards the right hand end of the apparatus and will then be driven on to the next annular surface B_2. The process continues, this time the fluid etc. being driven towards the left hand end of the apparatus, where it will then be driven on to the next annular surface B_3. The process further continues until finally the fluid etc. being centrifuged is forced through the quadrantal slots D into the peripheral flange-like portion H. The fluid etc. will then, under the action of centrifugal force, cling to the inner periphery of the portion H. Extending within this portion H is a stationary scoop J. In relation to Figure 2 the apparatus is regarded as being driven anticlockwise. Thus the scoop J will dip into the annular bulk of the centrifuged fluid etc., and this will be forced into the passageway K, whence it will leave the apparatus via the tubular extension L of passageway K.

In the application of this apparatus to the oxygenation of blood, the blood is caused to move rapidly in a film over a tortuous path provided by the annular surface B_1 . . . . B_2 . . . . etc. as mentioned above.

It will be seen that two inlet openings C_1, C_2 have been referred to. Of these openings one may serve as an inlet for blood, in which case the other may serve as an opening for the admission of oxygen from a source of compressed oxygen.

The high speed rotation of the apparatus will cause the blood to flow through the apparatus in a very thin film. By this means a thin film of blood over a large surface area facilitates the chemical combination of oxygen therewith. Furthermore, air bubbles are either prevented from forming, or if already existing, are dispersed. The other embodiment of the invention illustrated in Figures 3 and 4 is intended to operate on

substantially the same principle as the embodiment of Figures 1 and 2. In figure 3, therefore, part only of the apparatus is shown. The main difference between the apparatus of Figures 3 and 4 and that of Figures 1 and 2 is that the use of a separate scoop is avoided. Instead, in the annular portion H, a peripheral trough M is provided to constitute a discharge outlet having an outlet pipe N. As in the case of the apparatus of Figures 1 and 2 the outlet for the blood (or whatever material is being centrifuged), namely the trough M and pipe N, is maintained stationary.

It will be seen that in both embodiments described above, the tortuous path referred to is provided by a succession of interleaved frusto-conical sleeve-like portions of successively increasing diameters. If desired a further sleeve may be provided encircling the sleeve-like portions just mentioned, so as to provide an annular jacket for circulating cooling or warming fluid.

If desired, a filter may be provided in either of the embodiments described above, for the purpose of filtering blood which has been oxygenated. In the case of the embodiment of Figures 1 and 2 this filter may take the form of an annular metal gauze element extending over the quadrantal slots D to the immediate left thereof in relation to Figure 1. In the case of the embodiment of Figures 3 and 4 the filter may take the form of an annular metal gauze element, of generally "C" shape in cross-section, concentric with the trough M and lying moderately close thereto within the portion H.

A further embodiment of the invention is shown in Figures 5 and 6. In this embodiment the frusto-conical surfaces B_1, B_2, B_3 are replaced by the surfaces of two interleaved members of spiral cross-section P and Q, which spiral outwardly at a small angle, from near the axis of rotation. The elements P and Q are mounted between end chocks PQ and P^1Q^1 in the cylindrical container A and extend substantially the whole length thereof. The liquid to be centrifuged is delivered to the right-hand end of the two members through ports R and R^1 in the hollow shaft E and will progress outwardly over these elements under the action of centrifugal force. Progression of the fluid axially along the elements P and Q may be achieved by applying a taper to the two elements so that they expand in the direction towards which the fluid is required to flow. However, it is not necessary to do this since the chock PQ will prevent flow of the fluid from that end of the assembly and the fluid will progress away from the end by the action of centrifugal force which can be regarded as providing an "artificial gravity" tending to flatten the fluid and spread it over the surface in the only direction in which it is free to go, namely away from chock PQ. Alternatively it is sufficient to provide small beads on the edges of the members P and Q to impede flow of fluid off the edges to produce the same result.

At the left-hand end of the container A the elements P and Q deliver the fluid through ports S to the inside of the collecting portion H which in turn delivers fluid through a peripheral port H^1 into a stationary collecting funnel T.

The passage for the flow of the fluid through the funnel T is formed between the outer shell T and an inner member T^1 supported in spaced, parallel relation to the conical inner surface of the member T on studs T^{11}. The conical member T^1 carries in the centre of its base a bearing U which supports the left-hand end of the central shaft E. The clearance between the rotating collecting portion H of the centrifuge and the stationary member T, T^1 is made as small as possible so that the effect is obtained of a hydraulic seal between these two surfaces. Leakage of fluid through the small clearance between these surfaces is opposed by the centrifugal effect due to rotation of the portion H.

If the apparatus is to be used for interaction between a liquid and a gas the gas is introduced into the container A through a tube C_2 which passes through the hollow portion of the shaft E as in the previous example. Gas is fed to the tube C_2 through a rotating joint W and fluid to the ports R, R^1 through a rotating joint W_1.

The advantage of the modification just described is that if it is to be used for the oxygenation of blood the flow of the blood through the apparatus is free from any situation in which the blood is splashed in such a way that it might be damaged. Thus, whereas in the arrangement shown in Figure 1 the blood sprays outwardly from the right-hand end of surface B_1 onto the surface B_2, and similarly from the left-hand end of B_2 onto B_3 and so on, in this last embodiment no such spraying takes place, the flow taking place smoothly over the surfaces P and Q, smoothly from the interior of the container A into the collecting portion H and so to the bulk collected in the funnel portion T. The danger of damage to the blood is thus reduced to a minimum.

Various modifications may be made in the embodiments described without exceeding the scope of the invention.

WHAT WE CLAIM IS:—

1. Centrifuging apparatus comprising a rotatable container having within it at least one centrifuge member defining a tortuous path of large surface area extending between an axially located inlet opening and at least one peripherally disposed outlet opening, means for delivering fluid to be centrifuged

to said inlet opening and means for collecting said fluid from said outlet opening, whereby when said centrifuge member is rotated fluid introduced through said inlet opening is spread upon said surface and progressed filmwise towards said outlet opening by centrifugal action.

2. Apparatus as claimed in claim 1 wherein said path is defined by a succession of frusto-conical surfaces of small vertical angle, mounted for rotation about the axis of the centrifuge member.

3. Apparatus as claimed in claim 2 comprising a plurality of interleaved frusto-conical surfaces extending in opposite directions from end support members.

4. Apparatus as claimed in claim 3 wherein one of said end support members defines a rotationally symmetrical cavity and means for collecting fluid from a peripheral region of said cavity.

5. Apparatus as claimed in claim 4 including a stationary scoop extending radially within the cavity defined by said end support member and presenting an intake opening adjacent the periphery of said cavity for the reception of fluid collected within said cavity.

6. Apparatus as claimed in claim 4 wherein said end support member includes a peripheral trough and means for withdrawing fluid from said trough, said trough and said means being mounted in relation to said end support for movement relative thereto and being maintained stationary while said support is rotated.

7. Apparatus as claimed in claim 6 including gas inlet means communicating with the interior of said container and constituting means for the introduction of gas to be interacted with said fluid.

8. Apparatus as claimed in claim 1 wherein said centrifuge member is in the form of a wall member wound into a spiral, spiralling in one dimension outwardly from adjacent the axis of said container towards the outer wall thereof and extending in its orthogonal dimension substantially parallel to said axis, and said inlet means is arranged to deliver fluid to at least one point adjacent the axially located edge of said wall member and adjacent the end thereof remote from said collecting means and means for impeding flow of fluid over said wall member in the direction away from said collecting means.

9. Apparatus as claimed in claim 8 including a plurality of such wall members interleaved one with the other and means for delivering fluid to be centrifuged to at least one point adjacent each axially located edge of said wall members and adjacent the ends thereof remote from said collecting means.

10. Apparatus as claimed in claim 8 comprising collecting means including a peripherally located discharge opening for said container, a stationary receiving shell surrounding said discharge opening and a fluid seal between said stationary shell and said rotatable container.

11. Modification of the apparatus claimed in claim 8 in which the wall member is tapered in the axial direction towards a larger diameter at the end of said container at which the collecting means is located.

12. Centrifuging apparatus substantially as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

13. Centrifuging apparatus substantially as hereinbefore described with reference to Figures 3 and 4 of the accompanying drawings.

14. Centrifuging apparatus substantially as hereinbefore described with reference to Figures 5 and 6 of the accompanying drawings.

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Agent for the Applicants

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987023 COMPLETE SPECIFICATION
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

FIG.5.

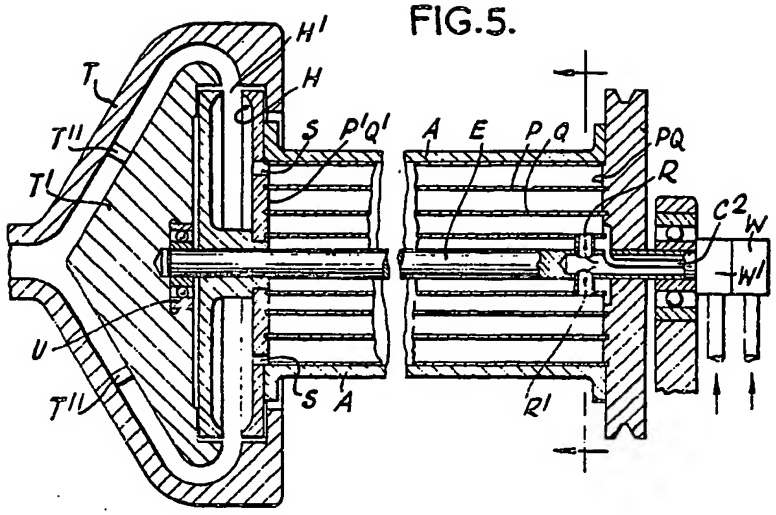
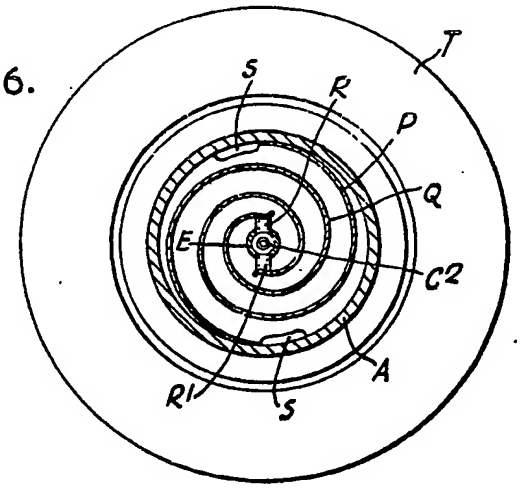


FIG.6.



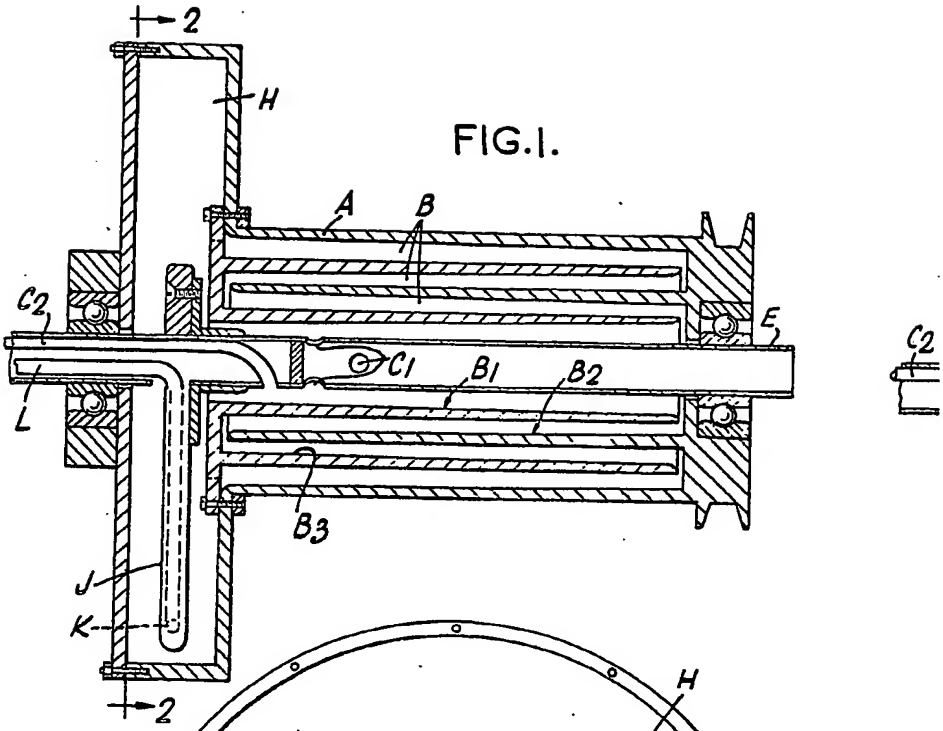


FIG.1.

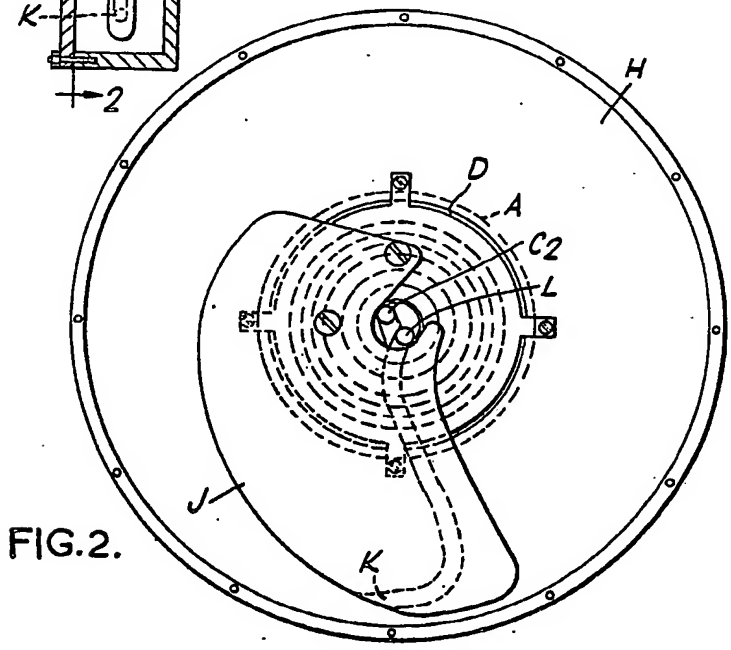


FIG.2.

987023 PROVISIONAL SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheets 1 & 2

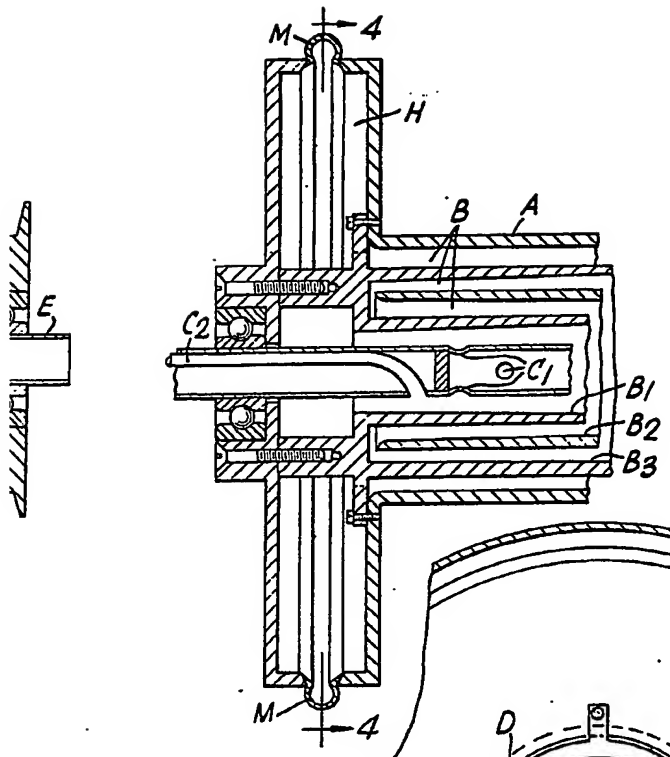


FIG.3.

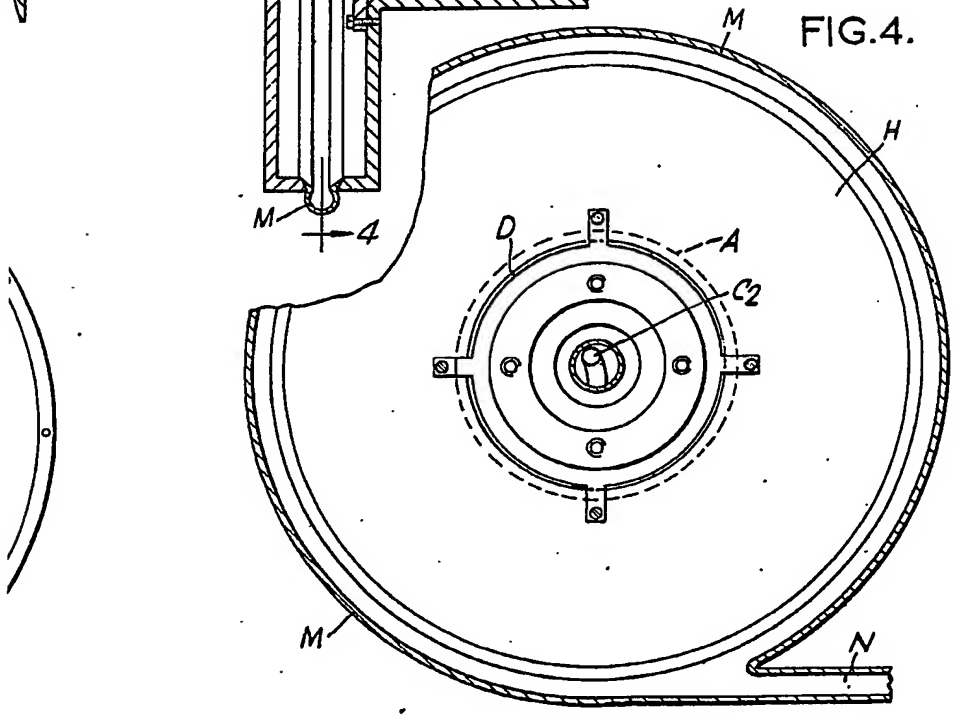
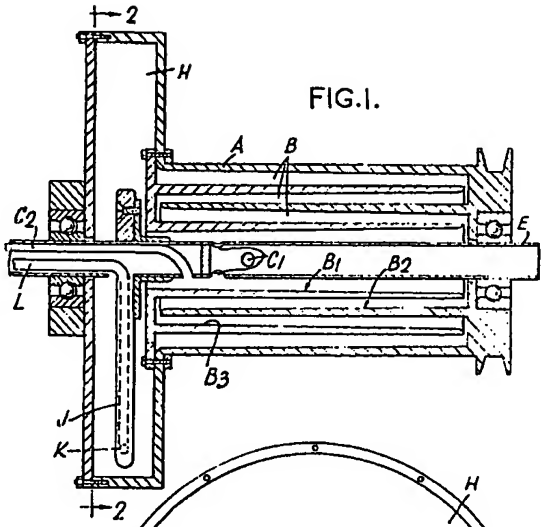


FIG.4.

987023 PROVISIONAL SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheets 1 & 2

FIG.1.



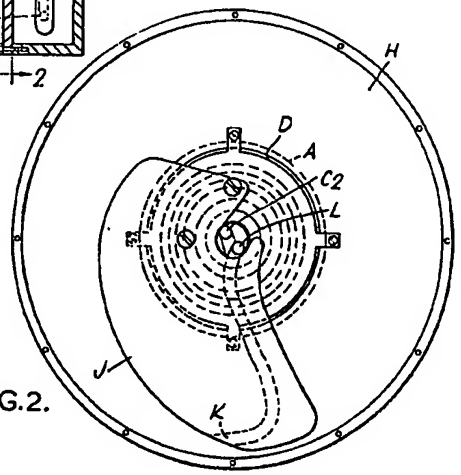


FIG.2.

FIG.3.

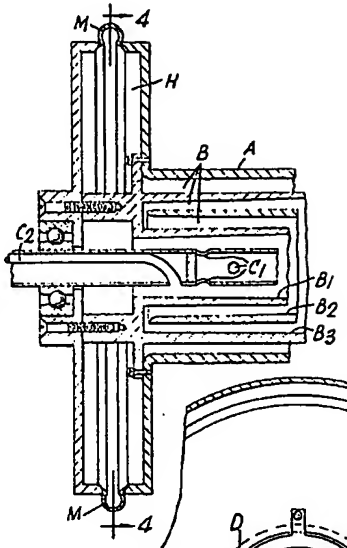


FIG.4.